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PROCESS FOR SEPARATING NH₃, AND OPTIONALLY ALSO CO₂ AND H₂O, FROM A
MIXTURE CONTAINING NH₃, CO₂ AND H₂O

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The invention relates to a process for separating NH₃ from a mixture containing NH₃, CO₂ and H₂O which comprises an NH₃ rectification step carried out in an NH₃ separation device to which one or more streams containing NH₃, CO₂ and H₂O, including the mixture, are supplied, with a stream consisting substantially of gaseous NH₃ being formed in the NH₃ separation device, separated from the mixture and removed.

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Such a process is known from NL 7804668 A. In the known process, which can find application in processes for the preparation of melamine or urea or the combined preparation of melamine and urea, the mixture supplied to the NH₃ separation device is gaseous or liquid. The NH₃ separation device is designed as a distillation device; the energy requirement is met by means of steam. The gaseous NH₃ stream that is formed comprises more than 95 wt% NH₃ and comprises further inert gases. The gaseous NH₃ stream does not contain CO₂. The gaseous NH₃ stream is partly condensed, with liquid NH₃ being formed. The liquid NH₃ is returned to the NH₃ separation device. The remaining mixture is discharged from the NH₃ separation device. In subsequent steps a stream consisting substantially of CO₂ and a stream consisting substantially of H₂O can be separated from the mixture.

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A disadvantage of the known process is that the NH₃ separation device is difficult to control. The composition, pressure and temperature are such that normal fluctuations in the process operation entail the danger of solids being formed. If this takes place, the solids must be removed by flushing with water, as a result of which the efficiency of the NH₃ separation device decreases.

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It is the object of the invention to reduce said disadvantage.

Said object is achieved in the process according to the invention in that a condensation step is carried out on at least one of the stream consisting substantially of gaseous NH₃ or the one or more streams containing NH₃, CO₂ and H₂O that are supplied to the NH₃ separation device, with at least a part of the CO₂ that is present being converted to a liquid phase.

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An advantage of the process according to the invention is that the danger

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of solids being formed in the NH_3 separation device is less than in the known NH_3 separation device. This reduces the need for efficiency-impairing measures such as the said water flushing operation, so that the process is more stable at a lower consumption of energy, for example in the form of steam, and as a result is cheaper.

5 Without intending to give a theoretical explanation of the advantages of the process according to the invention, it is being assumed that the conversion to a liquid phase of CO_2 has such an effect on the ratios in the NH_3 rectification step between NH_3 , CO_2 and H_2O and/or the phase in which they are present that there is less danger of solids being formed. In addition, it is being assumed that it is possible to enlarge the operational
10 possibilities of composition, pressure and temperature in the NH_3 separation device in such a way that there is less danger of solids being formed.

 The process according to the invention is applied to a mixture containing NH_3 , CO_2 and H_2O . The ratios between NH_3 , CO_2 and H_2O can vary within wide limits, as can the pressure and the temperature of the mixture. Preferably no solid material is
15 present in the mixture. In addition, the way in which the NH_3 rectification step to be discussed hereinafter is carried out may affect the possible ratios between NH_3 , CO_2 and H_2O , such as in the case of application of distillation in the NH_3 rectification step. In that case it is important, as for example cited in NL 7804668 A, to take into account the known azeotropic nature of mixtures of NH_3 , CO_2 and H_2O . As a result, at a given composition
20 and pressure only pure NH_3 can be separated using ordinary distillation if the composition is in the so-called NH_3 -rich range, i.e. range I in Fig. 1 of NL 7804668 A. Analogously, only pure CO_2 can be separated using ordinary distillation if the composition is in the CO_2 -rich range, i.e. range II in Fig. 1 of NL 7804668 A.

 If the mixture is present in, or originates from, processes known per se for
25 the preparation of melamine or urea, the mixture generally contains between 20 and 70% NH_3 , between 10 and 50% CO_2 and between 10 and 70% H_2O . Preferably the mixture contains between 25 and 60% NH_3 , between 15 and 40% CO_2 and between 20 and 55% H_2O . More preferably the mixture contains between 30 and 50% NH_3 , between 15 and 25% CO_2 and between 25 and 50% H_2O . Unless stated otherwise, said percentages here
30 and hereinafter are weight percentages.

 In the process according to the invention a NH_3 rectification step is understood to mean a step, applied to the mixture, in which separation technology is used

to form a stream that consists substantially of NH_3 . In principle every separation technology is suitable which ensures that the stream consisting substantially of gaseous NH_3 is formed, separated from the mixture and can be discharged. Examples of possible separation technologies are membrane separation and distillation. Preferably distillation is applied.

It can be useful or necessary for one or more additional streams to be supplied to the NH_3 rectification step that influence the thermodynamic equilibrium. An additional stream can also be supplied with the aim of separating NH_3 from it, as in the case of the mixture. The additional streams can contain NH_3 and/or CO_2 and/or H_2O .

Examples of additional streams are liquid NH_3 and recirculation streams from further process steps applied to the mixture. The NH_3 rectification step is carried out in an NH_3 separation device. If distillation is chosen as the separation technology, the pressures usually lie between 0.1 and 6 MPa, preferably between 0.3 and 4 MPa, more preferably between 0.6 and 3 MPa; the temperature usually lies between 5 and 160°C.

The stream consisting substantially of gaseous NH_3 that is formed in the NH_3 separation device and separated from the mixture is discharged. Besides NH_3 said stream may also contain small quantities of other compounds such as CO_2 and H_2O ; preferably the stream consisting substantially of gaseous NH_3 contains less than 15% other compounds, more preferably less than 10%, even more preferably less than 8%, and most preferably less than 5% or even less than 1%. The separation effort required to further reduce the quantity of other compounds can be weighed against the quantity of the other compounds that is allowable in the light of further application of the stream consisting substantially of gaseous NH_3 . In addition, if allowing a certain quantity of CO_2 in the stream consisting substantially of gaseous NH_3 , for example 5% or less, leads to a simplification or stabilization of the operation of the NH_3 separation device, it is advantageous to apply the condensation step according to the invention, which will be discussed later, at least to the stream consisting substantially of gaseous NH_3 .

In the process according to the invention a condensation step is applied to at least one of the stream consisting substantially of gaseous NH_3 or the one or more streams containing NH_3 , CO_2 and H_2O supplied to the NH_3 separation device. The condensation step can be carried out by means of techniques known per se. Examples of such techniques are: cooling by means of direct contact with a cooling medium and/or by

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indirect cooling in a heat exchanger and/or contact with a liquid absorbing medium. At least a part of the CO₂ that is present is converted to a liquid phase. The liquid phase may already be present during the condensation step, for example because the condensation step is carried out on a gas/liquid mixture; the liquid phase can also be formed during the condensation step, for example because gaseous H₂O condenses in which the CO₂ as well as NH₃ is absorbed; the liquid phase may also be supplied, such as the liquid absorbing medium as mentioned above. Preferably between 40% and substantially all CO₂ that is present is brought into a liquid phase; more preferably between 50% and substantially all CO₂ that is present is converted to a liquid phase, even more preferably between 75% and 99% or 95%.

The process according to the invention can be applied with the aim of obtaining the stream consisting substantially of gaseous NH₃ from the mixture. It may in addition be desirable to also free CO₂ and H₂O from the mixture, besides NH₃. The process according to the invention therefore further preferably comprises, in order to separate CO₂ and H₂O from the mixture:

- a CO₂ rectification step, which is applied in a CO₂ separation device to the mixture coming from the NH₃ separation device while a stream coming from a desorption device is supplied, with a stream consisting substantially of CO₂ being formed in the CO₂ separation device and being separated from the mixture, and
- a desorption step, which is applied in the desorption device to the mixture coming from the CO₂ separation device, with a stream consisting substantially of H₂O being formed and being separated from the mixture, after which the mixture is returned to the NH₃ separation device and/or the CO₂ separation device.

The CO₂ rectification step can be carried out with the aid of techniques known per se, in a CO₂ separation device. Examples of such a technique are membrane separation and distillation. In the case of distillation the stream consisting substantially of CO₂ is the top product. If distillation is applied to the mixture and, as will usually be the case, mainly NH₃, CO₂ and H₂O are present, it is to be expected that account must be taken of the azeotropic behaviour mentioned earlier. The composition in the CO₂ separation device, this being the device in which the CO₂ rectification step is carried out, must be in the CO₂-rich range at the prevailing pressure. If the composition of the mixture supplied from the NH₃ separation device, also taking into account the composition of the

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stream coming from the desorption step, will result in the composition in the CO₂ separation device being outside the CO₂-rich range, an additional measure is necessary. Examples of such additional measures are: a change in pressure, for example a pressure increase, and/or a change in composition, for example by supplying an additional stream
5 such as an H₂O stream. If a pressure increase is applied the pressure in the CO₂ separation device usually lies between 0.5 and 10 MPa, more preferably between 1 and 6 MPa and in particular between 1.5 and 5 MPa. The top temperatures in the CO₂ separation device then usually lie between 30 and 175°C, preferably between 100 and 150°C, the bottom temperatures usually between 100 and 250°C, preferably between 150
10 and 200°C.

As indicated above, from the CO₂ rectification step a stream consisting substantially of CO₂ is released. In addition the mixture is released; the mixture is removed from the CO₂ separation device and subsequently supplied to the desorption device where the desorption step is carried out. The aim of the desorption step is to free a stream
15 consisting substantially of H₂O from the mixture. This can take place with the aid of techniques known per se, such as with distillation, in which case the stream consisting substantially of H₂O is the bottom product. After a stream consisting substantially of H₂O has been separated from the mixture in the desorption step, the remaining quantity of the mixture, which still contains NH₃, CO₂ and H₂O, is returned to the NH₃ separation device
20 and/or the CO₂ separation device.

In this embodiment the condensation step according to the invention is carried out on the stream consisting substantially of gaseous NH₃ from the NH₃ separation device and/or on at least a part of the stream that comes from the desorption device and that is supplied to the NH₃ separation device.

In a special embodiment of the invention the desorption step is carried out in two desorption zones, one zone being operated at a pressure that is almost equal to the pressure in the NH₃ separation device and the second one at a pressure that is almost equal to the pressure in the CO₂ separation device. The streams leaving the desorption zones are transferred to the two separation devices at the practically corresponding
25 pressures. It was found that this can yield a reduction in steam consumption.
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If the condensation step according to the invention is applied to the stream consisting substantially of gaseous NH₃, this is done preferably in a submerged

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condenser with an aqueous stream and/or liquid NH_3 being supplied as absorbing medium. A submerged condenser is known per se, for example from NL 8400839 A. The aqueous stream consists substantially of water but may in addition also contain other compounds; examples are NH_3 , CO_2 , ammonium carbamate, melamine or urea. In the
5 submerged condenser the stream consisting substantially of gaseous NH_3 comes into direct contact with the also supplied aqueous stream and/or liquid NH_3 , in which CO_2 will absorb. This has the advantage that less stringent requirements are specified for the CO_2 removal in the NH_3 separation device than in the known process, which enhances the operational stability and reduces the risk of solids being formed. As stated earlier, the
10 formation of solids leads to steam consumption that is occasionally and/or structurally higher. Also, through the choice of the feed streams and their temperatures, optimum heat transfer and mass transfer conditions can be chosen, which is especially favourable as regards the transition of CO_2 from the gas phase to the liquid phase in the submerged condenser.

15 If the stream consisting substantially of gaseous NH_3 , after leaving the submerged condenser and as a result of the contact with the aqueous stream, contains an undesirable quantity of H_2O , preferably an absorption step is applied to the stream consisting substantially of gaseous NH_3 , in which said stream is brought into contact with liquid NH_3 . As a result, the H_2O will be absorbed in the liquid NH_3 . The absorption step can
20 be carried out with the aid of techniques known per se, for example in a plate column.

In another embodiment of the condensation step according to the invention this step is carried out as a partial condensation step on the stream that comes from the desorption device and that is supplied to the NH_3 separation device. The partial condensation step is preferably carried out by means of indirect cooling with a cooling
25 medium, in for example a heat exchanger. The stream coming from the desorption device also contains H_2O and NH_3 ; as a result of the partial condensation step at least a part of the H_2O will become liquid, in which a part of the CO_2 is absorbed as well as a part of the NH_3 . As a result, operation of the NH_3 separation device becomes simpler, and more stable on account of a smaller risk of solids being formed. Preferably the mixture present
30 in the NH_3 separation device is used as cooling medium in the partial condensation step.

The process according to the invention is explained further on the basis of the drawings.

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In the drawings Figure 1 shows an embodiment according to the known state of the art, in which a stream consisting substantially of gaseous NH_3 is separated from a gaseous mixture of NH_3 , CO_2 and H_2O in an absorber;

Figure 2 shows an embodiment according to the invention, in which the
5 condensation step is carried out on both the stream consisting substantially of gaseous NH_3 and on the stream that comes from the desorption device and that is supplied to the NH_3 separation device.

The first digit of the numbers in the figures is the same as the number of the figure. If the last two digits of the numbers of different figures agree, the parts are the
10 same.

In Fig. 1 a mixture of NH_3 , CO_2 and H_2O is supplied via line 102 to NH_3 separation device 104, which is designed as a distillation column and is preferably operated at a temperature between 15 -160°C and at a pressure between 0.1 and 6 MPa. Air is also supplied to the NH_3 separation device 104, via line 106, to protect the
15 equipment against corrosion. The stream consisting substantially of gaseous NH_3 is discharged via line 108 to ammonia cooler 110; the mixture is discharged as a liquid solution of NH_3 and CO_2 in water via line 111 and transferred to a CO_2 separation device - not drawn. In ammonia cooler 110 almost all NH_3 is liquefied and discharged via line 112, partly to be recirculated via line 114 to NH_3 separation device 104, partly via 113 to be
20 used elsewhere. From ammonia cooler 110 there also comes a gas phase, which consists substantially of inert gases and some NH_3 and which is conveyed via line 116 to scrubber 118. In scrubber 118 the stream from line 116 is brought into contact with scrubbing water, a stream consisting substantially of water, which is supplied via line 120, as a result of which the NH_3 is absorbed in the scrubbing water, a solution of NH_3 in water being formed.
25 The inert gases are discharged via line 122; the solution of NH_3 in water is fed via line 124 to cooler 126, and afterwards partly recirculated via line 128 to scrubber 118, and partly recirculated via line 130 to NH_3 separation device 104, which is further fed via line 132 with a stream of H_2O and via line 134 with mixture from the desorption device, which is not shown. The stream of H_2O which is supplied via line 132 serves substantially to prevent
30 solids being formed in the NH_3 separation device 104 or for flushing thereof in case that solids formation has still taken place.

In Fig. 2 a mixture of NH_3 , CO_2 and H_2O is fed via line 202 to NH_3

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separation device **204**; the mixture supplied via **234** from the desorption device is subjected to the partial condensation step according to the invention in cooler **236**. As cooling medium use is made of mixture from the NH_3 separation device **204**, supplied via line **238**, after which the mixture is returned to the NH_3 separation device **204** via **240**. The

5 partly condensed mixture from the desorption device is supplied via line **242** to the NH_3 separation device **204**. The stream consisting substantially of gaseous NH_3 is fed via line **244** to submerged condenser **246**, where it is brought into contact with a part of the solution of NH_3 in water coming from cooler **226**, and with a stream of liquid NH_3 supplied via **214**, this resulting in the formation of a gas/liquid mixture that is supplied to gas/liquid separator

10 **250** via line **248**. In separator **250** the liquid phase is separated and discharged via line **252**, after which the liquid phase is combined with the mixture that is supplied via **202**; the gas phase is separated, discharged and supplied to ammonia cooler **210** via line **208**.

The process according to the invention is explained further on the basis of a comparative experiment and an Example. The comparative experiment was performed

15 according to the embodiment of Fig. 1; the Example was performed according to the embodiment of Fig. 2. The results are shown in the following tables.

Table 1 – Results of the comparative experiment (see Fig. 1)

Stream	P (MPa)	T (°C)	NH₃ (kg/h)	CO₂ (kg/h)	H₂O (kg/h)	N₂ (kg/h)	O₂ (kg/h)	Total (kg/h)
102	3	50	350	200	450			1000
106	2	80				4	1	5
108	2	50	680			10	3	693
111	2	136	320	250	660			1230
113	2	40	350					350
114	2	40	300					300
130	2	50	30		30			60
132	2	50			60			60
134	3	175	320	50	120	6	2	498

- The total quantity of steam of 4 MPa and 430°C required in the
- 5 comparative experiment was 700 kg/h. In order to prevent the formation of solids during operation, it was necessary to supply a stream of water via **132**.

Table 2 – Results of the example (see Fig. 2)

Stream	P (MPa)	T (°C)	NH ₃ (kg/h)	CO ₂ (kg/h)	H ₂ O (kg/h)	N ₂ (kg/h)	O ₂ (kg/h)	Total (kg/h)
202	3	50	350	200	450			1000
206	2	80				4	1	5
208	2	50	450			10	3	463
211	2	135	300	250	600			1150
213	2	40	350					350
214	2	40	70					70
230	2	50	30		50			80
232					0			0
234	3	170	300	50	100	6	2	458
242 (gas)	3	135	230	20	15	6	2	273
242 (liquid)	3	135	70	30	85			185
244	2	100	530	10	20	10	3	573
252	2	50	180	10	70			260

- The quantity of steam of 4 MPa and 430°C required in the comparative experiment was 650 kg/h. During plant operation it was found that in the Example no formation of solids occurred, although no stream of water was supplied via 232 as was necessary in the comparative experiment. This proves the stabilizing effect of the condensation step according to the invention. In addition the quantity of required steam proves to be lower in the Example than in the comparative experiment, although the same quantity of mixture is processed. This lower steam requirement is an additional advantage of the process according to the invention.